COMPARISON OF EXPERIMENTAL DATA TO THAT OFA SEMI-EMPIRICAL MODEL FOR HELICAL MCG'S

P.T. Tracy
Tracy Physical Sciences Research
Huntsville, AL
Ptracy1458@aol.com

Ya. Tkach
Institute of Electromagnetic Research
Kharkov, Ukraine
slt@iemr.vl.kharkov.ua

L.L. Altgilbers
Advanced Technology Directorate
U.S. Army Space and Missile Defense Command
P.O. Box 1500
Huntsville, AL 35807
Larry.Altgilbers@smdc.army.mil

Abstract

A semi-empirical model of helical magnetocumulative generators (MCGs) has been developed. Two constants that are independent of the type of helical generator and the nature of the load and a single adjustable variable (the characteristic time) have been identified. To verify this model, calculated results were compared to experimental data for four helical MCGs - the Mark IX, FLEXY-I, EF-3, and Ranchito generators. The calculated results are in good agreement with the experimental data, as well as those generated by other codes.

I. INTRODUCTION

Even though magnetocumulative generators (MCGs) have been in use for almost 50 years, their fundamental physics has not been systematically studied until recently. Texas Tech University is currently conducting a systematic experimental study of helical generators and the U.S. Army Space and Missile Defense Command (USASMDC) a theoretical study. The objective of USASMDC's effort is to benchmark a computer model that will allow them to study the physics of the helical generator in detail. In order to benchmark this model, calculated results were compared to experimental data for the Mark IX and Ranchito MCGs developed at Los Alamos National Laboratory (LANL), the FLEXY-I developed at Loughborough University in the United Kingdom, and the EF-3 developed at the Institute of Atomic Physics in Romania. A description of the mathematical model used in the code is provided in Paper P1-E30 of this conference.

II. COMPARISON OF CALCULATED TO EXPERIMENTAL RESULTS

The dimensions of each generator are presented in Table 1 and the measured or calculated initial current, detonation velocity, load inductance, and other values in Table 2.

A. Mark IX Generator

The Mark IX was tested with two different loads having inductances of 56.5 and 35 nH. These two generator tests are referred to as the Mark IX-1 and Mark IX-2, respectively. Using the parameter values from Table 2, the output current was calculated and is plotted in Figs. 1 and 2. For a load inductance of 35 nH, the peak value of the calculated current is ~27 MA and occurs at ~190 μs. According to [1], the measured average peak current is ~28 MA and occurs at approximately ~180 μs. For a load inductance of 56.5 nH, the peak value of the calculated current is ~25 MA and occurs at ~200 μs. The measured average peak current is ~24

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14. ABSTRACT
A semi-empirical model of helical magnetocumulative generators (MCGs) has been developed. Two constants that are independent of the type of helical generator and the nature of the load and a single adjustable variable (the characteristic time) have been identified. To verify this model, calculated results were compared to experimental data for four helical MCGs - the Mark IX, FLEXY-I, EF-3, and Ranchito generators. The calculated results are in good agreement with the experimental data, as well as those generated by other codes.

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MA and occurs at approximately ~200 μs. The calculated curve closely matches the curve given in [1] over the entire range of time that data was collected.

B. FLEXY I Generator

Using the values in Table 2, the output current of the FLEXY I was calculated and is plotted in Fig. 3. The calculated peak current is ~7.4 MA and occurs at ~150 μs. According to [2], the measured peak current is ~7.3 MA and occurs at ~150 μs. The calculated curve closely matches the measured curve over the time that data was measured.

C. EF-3 Generator

Using the parameter values in Table 2, the output current of the EF-3 was calculated and is plotted in Fig. 4. The calculated peak current is ~3.4 MA and occurs at ~200 μs. According to [2], the peak current is about ~2.8 MA and occurs at about ~190 μsec. At times less than 190 μs, the calculated currents are in close agreement with the measured values.

D. Ranchito Generator

Using the parameter values in Table 2, the output current of the Ranchito generator was calculated and is plotted in Fig. 5. The peak value of the current is calculated to be ~2.8 MA and occurs at ~190 μs. According to [3], the measured peak current was ~1.6 MA at 170 μs. The experimental curve abruptly ends at this point in time. At 170 μs, the calculated current is 1.6 MA and for times earlier than 170 μs, the calculated current closely matches the measured values. The calculated current goes to zero at 234 μs.

III. SUMMARY

In summary, this semi-empirical model that describes the physical operation of helical MCGs appears to give reasonable results over a relatively wide range of design and operating conditions. The two areas requiring further study are the time dependent behavior of the electrical resistance over the complete period of operation and the physical nature of the characteristic time. These studies are being carried out at the present time and will be the subject of future papers.

IV. REFERENCES

[1] C.M. Fowler and R.S. Caird, "The Mark IX Generator", Seventh IEEE Pulsed Power Conference, Monterey, CA, June 11-14 (1989) and private communications with C.M. Fowler.
[2] B.M. Novac, et al., "Design, Construction, and Testing of Explosive-Driven Helical Generators", Aug (1994).
[3] E.R. Parkinson, K.A. Jamison, et al., "Continued Benchmarking of an FCG Code", Proceedings of the 12th Pulsed Power Conference, Monterey (1999).

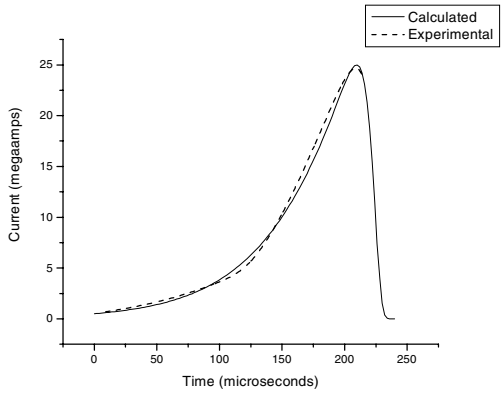

Figure 1. Calculated and Measured Output Measured Current of the Mark IX-1 Generator.

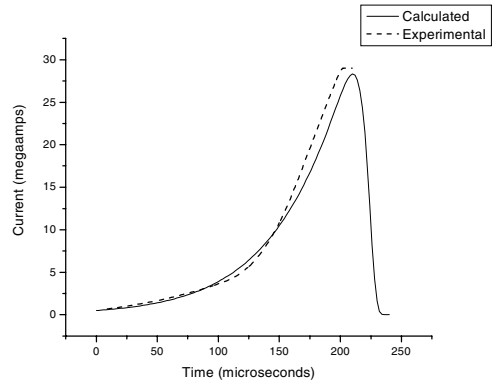

Figure 2. Calculated and Output Current of the Mark IX-2.

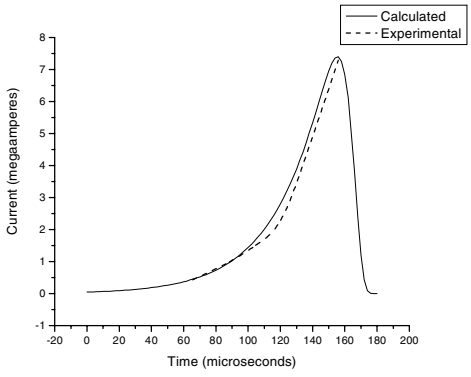

Figure 3. Calculated and Measured Output Current of the FLEXY I Generator.

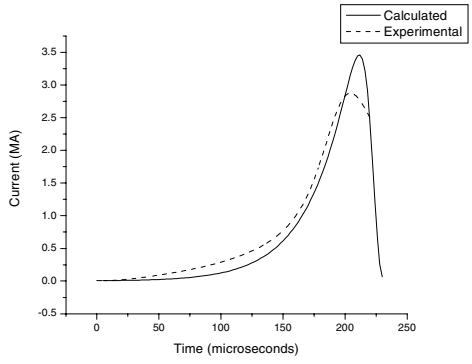

Figure 4. Calculated and Measured Output current of the EF-3 Generator.

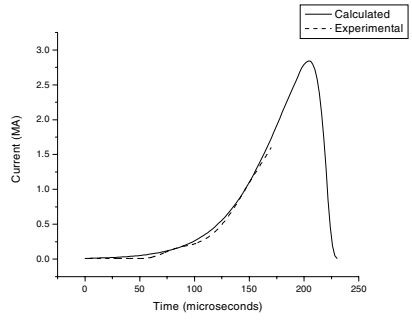

Figure 5. Calculated and Measured Output Current of the Ranchito Generator.

Generator	Number Of Sections	Stator Length (cm)	Stator Radius (cm)	Armature Length (cm)	Armature Radius (cm)	Initial Inductance (μH)
Mark IX	4	111.8	17.8	1730	8.65	9.445
EF-3	15	150	16	-	8	741.6
FLEXY I	8	112	21.2	-	10.6	59.4
Jemez	2	46.2	10.2	76.2	-	28.8
Ranchito	5		11.43			148.3

Table 1. Dimensions and Initial Inductance of the Helical Generators Under Investigation

Generator	I_0 (kA)	V_{det} (km/s)	R_0 (Ohms)	t_0 (μs)	τ (μs)	L_{load} (nH)
Mark IX-1	500	8.83	3.15×10^{-4}	196	48	35
Mark IX-2	500	8.83	3.15×10^{-4}	196	48	56.5
EF-3	10	8.25	0.0148	198	31	110
FLEXY I	48	8.2	0.00212	137	29.2	40
Jemez 01	4	8.4	0.0179	93.7	17.25	36.4
Jemez 02	20	8.4	0.00358	93.7	20.5	36.4
Ranchito		8.25	0.0148	198	30.7	330

Table 2. Initial and Calculated Values for the Helical Generators Under Investigation.